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Evolution of the Oxidation State of the Earth's Mantle

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The oxidation state of the Earth's mantle during formation remains an unresolved question, whether it was constant throughout planetary accretion [1], transitioned from reduced to oxidized [2,3,4], or from oxidized to reduced [1,5]. We investigate the stability of Fe³⁺ at depth, in order to constrain processes (water, late accretion, dissociation of FeO) which may reduce or oxidize the Earth's mantle.

In our previous experiments on shergottite compositions, variable fO₂, T, and P < 4 GPa, Fe³⁺/ΣFe decreased slightly with increasing P, similar to terrestrial basalt [6,7,8]. For oxidizing experiments < 7 GPa, Fe³⁺/ΣFe decreased as well [9], but it's unclear from previous modelling whether the deeper mantle could retain significant Fe³⁺ [1,10]. Our current experiments expand our pressure range deeper into the Earth's mantle and focus on compositions and conditions relevant to the early Earth. Preliminary multi-anvil experiments with Knippa basalt as the starting composition were conducted at 5-7 GPa and 1800 °C, using a molybdenum capsule to set the fO₂ near IW, by buffering with Mo-MoO₃. TEM and EELS analyses revealed the run products quenched to polycrystalline phases, with the major phase pyroxene containing \cong Fe^{3+/2+}. Experiments are underway to produce glassy samples that can be measured by EELS and XANES, and are conducted at higher pressures.

[1]Righter and Ghiorso, 2012; [2]Rubie et al., 2011; [3]Wood et al., 2006; [4]Wänke and Dreibus, 1988; [5]Siebert et al., 2013; [6] Righter et al., 2013; [7] O'Neill, et al., 2006; [8] Kress and Carmichael, 1991; [9] Zhang et al., 2013; [10] Hirschmann, 2012